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One Theory For Two Risk Premia

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Une Théorie pour Deux Primes de Risques

Résumé

Dans la présentation traditionnelle du modèle de l'espérance d'utilité, la prime de risque représente ce qu'un individu, averse au risque, est prêt à payer pour être débarrassé d'un risque. Dans cet article, nous introduisons une prime de risque différente qui répond à la question suivante : quelle espérance de gain un risque (qui peut être la rentabilité d'un actif financier) doit-il offrir pour être accepté par un agent averse au risque ? Bien que cette prime de risque découle du « bid price » défini par Pratt (1964), elle ne doit pas être confondu avec lui ; le « bid price » représentant la compensation monétaire du risque. La prime de risque traditionnelle fait référence à un comportement d'évitement du risque alors que notre prime de risque fait référence à un comportement de prise de risque. Nous revisitons les principaux résultats concernant l'aversion au risque dans le modèle de l'espérance d'utilité avec cette prime de risque et nous en déduisons ses principales propriétés.

Mots-clés : Choix en incertain, espérance d'utilité, aversion au risque, prime de risque.

One Theory For Two Risk Premia

Abstract

Generally, in the standard presentation of the expected utility model, the risk premium represents how much a risk-averse decision maker is ready to pay to have a risk eliminated. Here, however, we introduce a different risk premium: how much should a risk (which could be the return on a financial asset) yield to be acceptable to a risk-averse decision maker. Although our risk premium is derived from the Pratt bid price, it should not be confused with it: the Pratt bid price represents the monetary compensation of a risk. The standard risk premium refers to risk-avoidance; our risk premium, however, refers to risk-taking. We then reanalyse the main results concerning risk aversion under expected utility using this risk premium tool and deduce its main properties.

Keywords: choices under uncertainty, expected utility, risk aversion, risk premium.

JEL: D81.

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One Theory for Two Different Risk Premia

Emmanuelle Gabillon*

December 6, 2011

Abstract

Generally, in the standard presentation of the expected utility model, the risk premium represents how much a risk-averse decision maker is ready to pay to have a risk eliminated. Here, however, we introduce a different risk premium: how much should a risk (which could be the return on a financial asset) yield to be acceptable to a risk-averse decision maker. Although our risk premium is derived from the Pratt bid price, it should not be confused with it: the Pratt bid price represents the monetary compensation of a risk. The standard risk premium refers to risk-avoidance; our risk premium, however, refers to risk-taking. We then reanalyse the main results concerning risk aversion under expected utility using this risk premium tool and deduce its main properties.

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1 Introduction

The risk premium, originally introduced by Friedman and Savage (1948) and Pratt (1964) in the expected utility framework, is a characteristic of preferences, representing the monetary cost equivalent to the desutility of risk. This risk premium, which can be understood as the maximal amount of money that the decision maker (DM) is ready to pay to have a risk eliminated, constitutes a central concept in the theory of choice under uncertainty.

Here, we focus on another risk premium which represents how much a risk (which could be the return on a financial asset) should yield to be undertaken by a risk-averse decision maker. Even though our risk premium is derived from the Pratt (1964) bid price for the risk, it should not be confused with it: the Pratt bid price represents the monetary compensation of a risk. Whereas the Friedman-Savage-Pratt risk premium focusses on risk-avoidance, making it an appropriate tool for analyzing insurance problems, the risk premium we introduce here considers risk-taking, making it more appropriate for financial models.

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We therefore use this concept to reanalyze the Arrow (1971) portfolio problem, explaining why a risk-averse investor invests in a risky asset as soon as its expected rate of return is higher than the risk-free rate.

We also establish the relationships between the two risk premia: in general, these premia are not equal. We also show that the Friedman-Savage-Pratt risk premium shares many properties with our risk premium. Whenever this occurs, we indicate the similarities between our results and those of La Vallée (1968) in his comparison of the Pratt bid and ask prices.

In Section 1, after a brief presentation of the Pratt bid and ask prices, we define our risk-taking premium and use it to explain the results obtained by Arrow (1971) in his portfolio choice model. In Section 2, we focus on the properties of the risk-taking premium and on its links with the Friedman-Savage-Pratt risk premium.

2 The risk premia

First, we recall briefly the definition of the bid and ask prices introduced by Pratt (1964). We then introduce the risk-taking premium. In order to do so, we consider a risk-averse decision maker whose preferences are represented by a von Neumann-Morgenstern utility function $u(.)$. The function $u(.)$ is assumed to be increasing and concave.

2.1 The Pratt bid-ask prices and the risk-avoiding premium

Pratt (1964) defined an asking price P_a and a bid price P_b for a risk $\widetilde{y}$ that affects, in an additive way, the DM's wealth W. Pratt defined the asking price as 'the smallest amount for which the DM would willingly sell $\widetilde{y}$ if he had it':

$$u(W + P_a) = E[u(W + \widetilde{y})] \tag{1}$$

where E is the expectation operator.

The bid price P_b is defined as 'the largest amount the DM would willingly pay to obtain $\widetilde{y}$' which is given by

$$u(W) = E[u(W + \widetilde{y} - P_b)] \tag{2}$$

In his paper, Pratt concentrated on the risk premium associated with the asking price. Let π^u_{ay} denote this risk premium, which satisfies

$$u\left(W + E(\widetilde{y}) - \pi^u_{ay}\right) = E[u(W + \widetilde{y})] \tag{3}$$

This risk premium had previously been brought to light by Friedman and Savage (1948). The comparison of equation (1) and equation (3) gives

$$\pi^u_{ay} = E(\widetilde{y}) - P_a \tag{4}$$

The premium π^u_{ay} represents the maximal amount that the DM is willing to pay to obtain $E(\widetilde{y})$ instead of $\widetilde{y}$. This risk premium is to be found in any standard manual treating of economics under uncertainty. Since π^u_{ay} represents the DM's personal monetary appreciation of having the risk eliminated, we will refer to it here as the *risk-avoiding premium (RAP).*

2.2 The risk-taking premium

Let us decompose a risk $\widetilde{y}$ as follows:

$$\widetilde{y} = E(\widetilde{y}) + \widetilde{\varepsilon}_y \text{ with } E(\widetilde{\varepsilon}_y) = 0 \tag{5}$$

The risk $\widetilde{\varepsilon}_y$ is the zero-mean risk included in lottery $\widetilde{y}$ or, stated in another way, $\widetilde{\varepsilon}_y$ is the pure risk which characterizes lottery $\widetilde{y}$.

We can now introduce the definition of our *risk-taking premium* (RTP):

Definition 1
The risk-taking premium π^u_{by} represents the minimal expected payoff that risk $\widetilde{y}$ should yield to be acceptable for a risk-averse DM. RTP satisfies
$E\left[u\left(W + \pi^u_{by} + \widetilde{\varepsilon}_y\right)\right] = u(W)$

The RTP is the minimal expected payoff that risk $\widetilde{y}$ should yield to have pure risk $\widetilde{\varepsilon}_y$ accepted by the DM, while the RAP is the maximal amount that the DM is ready to pay to have pure risk $\widetilde{\varepsilon}_y$ eliminated.

From Equations (2) and (5) and Definition 1, we obtain the relation between the RTP and the bid price

$$\pi^u_{by} = E(\widetilde{y}) - P_b \tag{6}$$

We obtain the following proposition:

Proposition 1
If $E(\widetilde{y}) > \pi^u_{by}$ then the DM prefers to take risk $\widetilde{y}$.
If $E(\widetilde{y}) = \pi^u_{by}$ then the DM is indifferent as to taking or not taking risk $\widetilde{y}$.
If $E(\widetilde{y}) < \pi^u_{by}$ then the DM prefers not to take risk $\widetilde{y}$.

Proof. Function $u(.)$ being increasing, $u(W) = E\left[u\left(W + \pi^u_{by} + \widetilde{\varepsilon}_y\right)\right] \lesseqgtr E\left[u\left(W + E(\widetilde{y}) + \widetilde{\varepsilon}_y\right)\right]$ if $\pi^u_{by} \lesseqgtr E(\widetilde{y})$. ■

Proposition 1 states that the DM will take a risk if the expected payoff is large enough. Although the general idea is not new, we still need to know what 'large enough' means: the precise definition of this is given here by π^u_{by}.

This RTP π^u_{by} can then easily be used to analyse the portfolio decision problem presented by Arrow (1971). The DM can choose to invest in a risky asset and in a riskless one. By normalizing the risk-free rate to zero and noting m the amount invested in the risky asset, the DM's programme can be written

$$\underset{m}{Max} E\left[u\left(W + m\widetilde{y}\right)\right] \tag{7}$$

where $\widetilde{y}$ represents the risky asset rate of return.

If m^* denotes the optimal investment in the risky asset, Arrow showed that $m^* > 0$ as soon as $E\left(\widetilde{y}\right) > 0$. This result, which might appear surprising at first sight, is not in contradiction with Proposition 1 which states that the DM accepts to take a risk only if its expected payoff is large enough. On the contrary, risk premium π^u_{by} can help us understand Arrow's result. We therefore introduce RTP π^u_{bmy} which satisfies

$$E\left[u\left(W + \pi^u_{bmy} + m\widetilde{\varepsilon}_y\right)\right] = u\left(W\right) \tag{8}$$

where $m\widetilde{\varepsilon}_y$ represents the level of investor risk exposure.

This gives the following proposition:

Proposition 2
$\forall E\left(\widetilde{y}\right) > 0$ *(even if very small), there exists* $\widehat{m} > 0$ *(which may be very small) such that* $\forall m \leq \widehat{m}$, $\pi^u_{bmy} < mE\left(\widetilde{y}\right)$.

Proof. See Appendix A. ∎

Thus, even if $E\left(\widetilde{y}\right)$ is very small, as soon as it is strictly positive, the optimal investment in risky asset m^* is strictly positive. This is because when m is small enough, the minimal expected rate of return π^u_{bmy} that the risky asset should yield to be desirable is lower than its real yield $mE\left(\widetilde{y}\right)$. As Arrow indicated: 'for small amounts at risk, the utility function is approximately linear, and risk aversion disappears'. In the present paper, we develop the mechanism underlying Arrow's assertion by showing that π^u_{bmy} tends towards zero more rapidly than $mE\left(\widetilde{y}\right)$.

Arrow also showed that m^* is increasing in wealth when the coefficient of absolute risk aversion $A^u\left(W\right) = -\frac{u''(W)}{u'(W)}$ is decreasing. We shed further light on this result in the next section.

3 The risk-taking premium properties

In what follows, as it is more appropriate to present π^u_{by} as a function of W, we have adopted the notation $\pi^u_{by}(W)$.

We establish the links between the RAP and the RTP:

Proposition 3
For any risk $\widetilde{y}$, $\forall W$, $\pi^u_{by}(W) = \pi^u_{ay}\left(W + \pi^u_{by}(W) - E(\widetilde{y})\right)$ *and* $\pi^u_{ay}(W) = \pi^u_{by}\left(W - \pi^u_{ay}(W) + E(\widetilde{y})\right)$

Proof. See Appendix B. ■

The first relation defines $\pi^u_{ay}(W)$ starting from $\pi^u_{by}(W)$, and the second relation defines $\pi^u_{by}(W)$ starting from $\pi^u_{ay}(W)$. Since Equation (4) establishes a relation between the RAP and the ask price and Equation (6) establishes a relation between the RTP and the bid price, Proposition 3 can be rewritten using both the ask and bid prices. This allows us to obtain the results of La Vallée (1968), although those came from a different framework. La Vallée (1968) studied the ask price required by a DM for taking a decision under uncertainty on the basis of certain information. He also studied the price offered by the DM in exchange for selling this possibility.

Proposition 3, which gives the relation between the two risk premia, generates three corollaries.

In the first two of these, we highlight the symmetry between the two risk premia. Pratt (1964) had previously demonstrated that $\pi^u_{ay}(W)$ is decreasing when $A^u(W)$ is decreasing in wealth, which is the most reasonable assumption about risk aversion. We demonstrate a similar property using the RTP.

Corollary 1
If, for any $\widetilde{y}$, $\pi^u_{ay}(W)$ *is decreasing in wealth then, for any risk* $\widetilde{y}$, $\pi^u_{by}(W)$ *is decreasing in wealth.*

Proof. See Appendix C. ■

Given Corollary 1, if $A^u(W)$ is decreasing in wealth, then $\pi^u_{by}(W)$ is also decreasing in wealth. This property also applies to risk premium $\pi^u_{bmy}(W)$ which characterizes the Arrow portfolio problem (see Equation 8). This result allows us to understand why m^* is an increasing function of wealth: the difference $mE(\widetilde{y}) - \pi^u_{bmy}(W)$, which justifies an investment in the risky asset, increases with wealth.

Pratt (1964) demonstrated that agent v is more risk averse than agent u if and only if $\forall\widetilde{y}, \forall W$, $\pi^v_{ay}(W) \geq \pi^u_{ay}(W)$. We demonstrate that this property can also be written using the RTP.

Corollary 2
The two statements are equivalent:
For any risk $\widetilde{y}$, $\forall W$, $\pi^v_{ay}(W) \geq \pi^u_{ay}(W)$.
For any risk $\widetilde{y}$, $\forall W$, $\pi^v_{by}(W) \geq \pi^u_{by}(W)$.

Proof. See Appendix D. ■

Whereas the two above-mentioned corollaries stress the symmetry between the two risk premia, the third corollary which follows allows us to compare and contrast the two premia.

Corollary 3
For any $\widetilde{y}$, *if* $\pi^u_{ay}(W)$ *is decreasing in wealth,*
$\pi^u_{by}(W) < \pi^u_{ay}(W)$ *when the risk is not desirable* ($\pi^u_{by}(W) > E(\widetilde{y})$).
$\pi^u_{by}(W) \geq \pi^u_{ay}(W)$ *when the risk is desirable* ($\pi^u_{by}(W) \leq E(\widetilde{y})$).

Proof. See Appendix E. ■

According to Corollaries 1 and 3, under decreasing absolute risk aversion, the risk premia behave as follows:

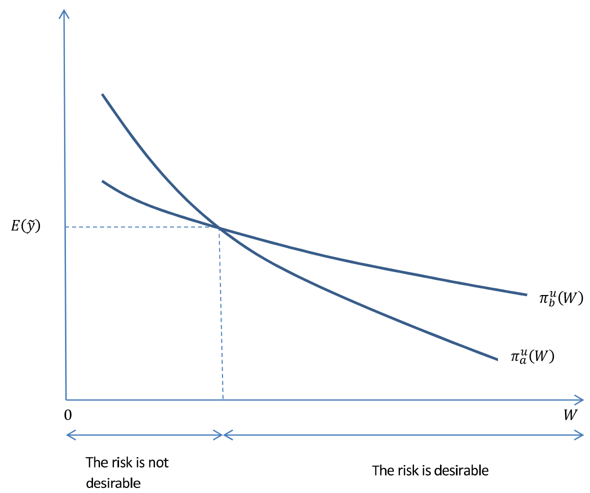

Figure 1: The two risk premia as functions of wealth under decreasing absolute risk aversion

When the coefficient of absolute risk aversion is not constant, there is asymmetry between the two risk premia which do not coincide[1]. La Vallée (1968) obtained similar results with the bid and ask prices. Under decreasing absolute risk aversion, he showed that the ask price is lower than the bid price when both

[1]Under constant absolute risk aversion, the RAP is constant and it is easy to see from Proposition 3 that the RTP is equal to the RAP.

prices are negative (the risk is not desirable) and higher when this is not the case (the risk is desirable).

4 Conclusion

In this paper, we envisage the risk premium in terms of risk-taking, unlike the standard approach which focusses on risk-avoidance. The equity premium observed on the financial market, which reflects the average investors' risk aversion, corresponds to the risk-taking premium definition developed in this paper.

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Appendix A

We deduce from Equation (8) that $\pi^u_{bmy} = 0$ when $m = 0$.

Moreover, deriving Equation (8) with respect to m yields

$$\frac{\partial \pi^u_{bmy}}{\partial m} = -\frac{E\left[u^{'}\left(W + \pi^u_{bmy} + m\widetilde{\varepsilon}_y\right)\widetilde{\varepsilon}_y\right]}{E\left[u^{'}\left(W + \pi^u_{bmy} + m\widetilde{\varepsilon}_y\right)\right]} \tag{A.1}$$

and

$$E\left[u^{'}\left(W + \pi^u_{bmy} + m\widetilde{\varepsilon}_y\right)\widetilde{\varepsilon}_y\right] = cov\left(u^{'}\left(W + \pi^u_{bmy} + m\widetilde{\varepsilon}_y\right), \widetilde{\varepsilon}_y\right) \tag{A.2}$$

where cov is the covariance operator.

Since, when $m \geq 0$ and $u(.)$ concave, the covariance is negative, we obtain

$$\forall m \geq 0, \frac{\partial \pi^u_{bmy}}{\partial m} \geq 0 \tag{A.3}$$

The premium π^u_{bmy} is increasing in m.

In particular, when $m = 0$, we have

$$\frac{\partial \pi^u_{bmy}}{\partial m}(m=0) = -\frac{u^{'}(W)\,E(\widetilde{\varepsilon}_y)}{E[u'(W)]} = 0 \qquad \text{(A.4)}$$

The derivative of π^u_{bmy} is equal to zero when $m = 0$.

Moreover, if we derive a second time Equation (8) with respect to m, we obtain

$$E\left[u''\left(W + \pi^u_{bmy} + m\widetilde{\varepsilon}_y\right)\left(\frac{\partial \pi^u_{bmy}}{\partial m} + \widetilde{\varepsilon}_y\right)^2\right]$$
$$+E\left[u'\left(W + \pi^u_{bmy} + m\widetilde{\varepsilon}_y\right)\frac{\partial^2 \pi^u_{bmy}}{\partial m^2}\right] = 0 \qquad \text{(A.5)}$$

As function $u(.)$ is increasing and concave, the above equation implies that

$$\forall m \geq 0, \frac{\partial^2 \pi^u_{bmy}}{\partial m^2} \geq 0 \qquad \text{(A.6)}$$

The premium π^u_{bmy} is convex with respect to m.

Equations (A.3), (A.4) and (A.6) give the following figure:

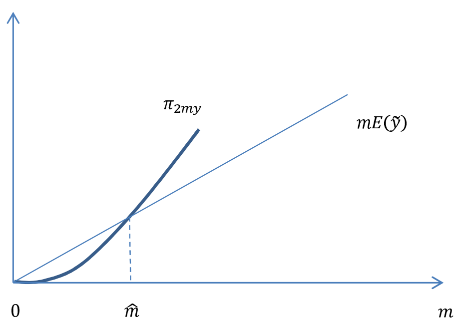

Figure 2: π^u_{bmy} decreases towards zero more rapidly than $mE(\widetilde{y})$

We can conclude that, $\forall E(\widetilde{y}) > 0$ (even if very small), there exists $\widehat{m} > 0$ (which may be very small) such that $\forall m < \widehat{m}$, $\pi^u_{bmy} < mE(\widetilde{y})$.

Appendix B

Using Definition 1, we have

$$E\left[u\left(W+\pi_{by}^{u}\left(W\right)+\widetilde{\varepsilon}_{y}\right)\right]=u\left(W\right)=u\left[W+\pi_{by}^{u}\left(W\right)-E\left(\widetilde{y}\right)+\left(E\left(\widetilde{y}\right)-\pi_{by}^{u}\left(W\right)\right)\right] \tag{B.1}$$

and

$$E\left[u\left(W+\pi_{by}^{u}\left(W\right)+\widetilde{\varepsilon}_{y}\right)\right]=E\left[u\left(W+\pi_{by}^{u}\left(W\right)-E\left(\widetilde{y}\right)+E\left(\widetilde{y}\right)+\widetilde{\varepsilon}_{y}\right)\right] \tag{B.2}$$

The above equation implies that

$$E\left[u\left(W+\pi_{by}^{u}\left(W\right)+\widetilde{\varepsilon}_{y}\right)\right]=u\left[W+\pi_{by}^{u}\left(W\right)-E\left(\widetilde{y}\right)+EC_{y}^{u}\left(W+\pi_{by}^{u}\left(W\right)-E\left(\widetilde{y}\right)\right)\right] \tag{B.3}$$

where $EC_{y}^{u}\left(W+\pi_{b\varepsilon}^{u}\left(W\right)-E\left(\widetilde{y}\right)\right)$ represents the certainty equivalent of $\widetilde{y}$ when the DM's wealth is $W+\pi_{b\varepsilon}^{u}\left(W\right)-E\left(\widetilde{y}\right)$.

Thus, from Equations (B.1) and (B.3), we obtain

$$E\left(\widetilde{y}\right)-\pi_{by}^{u}\left(W\right)=EC_{y}^{u}\left(W+\pi_{by}^{u}\left(W\right)-E\left(\widetilde{y}\right)\right) \tag{B.4}$$

As $EC_{y}^{u}\Big(W+\pi_{by}^{u}\left(W\right)-E\left(\widetilde{y}\right)\Big)=E\left(\widetilde{y}\right)-\pi_{ay}^{u}\Big(W+\pi_{by}^{u}\left(W\right)-E\left(\widetilde{y}\right)\Big)$, we obtain

$$\pi_{by}^{u}\left(W\right)=\pi_{ay}^{u}\left(W+\pi_{by}^{u}\left(W\right)-E\left(\widetilde{y}\right)\right) \tag{B.5}$$

We also have

$$E\left[u\left(W+E\left(\widetilde{y}\right)+\widetilde{\varepsilon}_{y}\right)\right]=u\left(W+EC_{y}^{u}\left(W\right)\right) \tag{B.6}$$

and

$$u\left(W+EC_{y}^{u}\left(W\right)\right)=E\left[u\left(W+EC_{y}^{u}\left(W\right)+\pi_{b\varepsilon}^{u}\left(W+EC_{y}^{u}\left(W\right)\right)+\widetilde{\varepsilon}_{y}\right)\right] \tag{B.7}$$

The above two equations imply that

$$E\left(\widetilde{y}\right)=EC_{y}^{u}\left(W\right)+\pi_{by}^{u}\left(W+EC_{y}^{u}\left(W\right)\right) \tag{B.8}$$

which gives

$$\forall W,\quad \pi_{ay}^{u}\left(W\right)=\pi_{by}^{u}\left(W-\pi_{ay}^{u}\left(W\right)+E\left(\widetilde{y}\right)\right) \tag{B.9}$$

Appendix C

Deriving Equation (B.9) with respect to W gives

$$\forall W,\ \pi_{ay}^{u\prime}(W) = \pi_{by}^{u\prime}\left(W - \pi_{ay}^{u}(W) - E(\widetilde{y})\right)\left(1 - \pi_{ay}^{u\prime}(W)\right) \tag{C.1}$$

Thus, $\forall W,\ \ \pi_{ay}^{u\prime}(W) \leq 0 \Rightarrow \forall W,\ \ \pi_{by}^{u\prime}(W) \leq 0$.

Appendix D

$\forall W$, we have $\pi_{ay}^{v}(W) \geq \pi_{ay}^{u}(W)$ if and only if any risk that is undesirable for agent u is also undesirable for agent v. This condition can be written as follows:

$$E[u(W + \widetilde{y})] \leq u(W) \Rightarrow E[v(W + \widetilde{y})] \leq v(W) \tag{D.1}$$

Using Equation (5) and Definition 1, the above condition becomes

$$E[u(W + E(\widetilde{y}) + \widetilde{\varepsilon}_y)] \leq u\left(W + \pi_{by}^{u}(W) + \widetilde{\varepsilon}_y\right)$$

$$\Rightarrow E[v(W + E(\widetilde{y}) + \widetilde{\varepsilon}_y)] \leq v\left(W + \pi_{by}^{v}(W) + \widetilde{\varepsilon}_y\right) \tag{D.2}$$

which is equivalent to

$$E(\widetilde{y}) \leq \pi_{by}^{u}(W) \Rightarrow E(\widetilde{y}) \leq \pi_{by}^{v}(W) \tag{D.3}$$

Or

$$\pi_{by}^{v}(W) \geq \pi_{by}^{u}(W) \tag{D.4}$$

Appendix E

Using Equation (B.5) we have

If $\pi_{ay}^{u}(W)$ is decreasing and the risk is not desirable to the DM, then

$$\forall W,\ \pi_{by}^{u}(W) = \pi_{ay}^{u}\left(W + \underbrace{\pi_{by}^{u}(W) - E(\widetilde{y})}_{\geq 0}\right) \leq \pi_{ay}^{u}(W) \tag{E.1}$$

If $\pi_{ay}^{u}(W)$ is decreasing and the risk is desirable to the DM, then

$$\forall W,\ \pi_{by}^{u}(W) = \pi_{ay}^{u}\left(W + \underbrace{\pi_{by}^{u}(W) - E(\widetilde{y})}_{<0}\right) > \pi_{ay}^{u}(W) \tag{E.2}$$

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